

**Probing the singlet character of the two-hole states
in cuprate superconductors**

G. Ghiringhelli^{*1}, N.B. Brookes², L.H. Tjeng³, T. Mizokawa⁵, O. Tjernberg⁶,
P.G. Steeneken³, A.A. Menovsky⁴

¹ *INFM, Politecnico di Milano, p. Leonardo da Vinci 32, 20133 Milano, Italy.*

² *ESRF, BP 220, 38043 Grenoble, France.*

³ *MSC, Univ. of Groningen, Nijenborgh 4, 9747 AG Groningen, Netherlands.*

⁴ *Univ. of Amsterdam, Valckenierstraat 65, 1018 XE Amsterdam, Netherlands.*

⁵ *University of Tokyo, Tokyo 113-0033, Japan.*

⁶ *Department of Physics, KTH, S-10044 Stockholm, Sweden.*

Using spin-resolved resonant photoemission we have probed the singlet *vs* triplet character of the two-hole state in the layered cuprates $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$, $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$, $\text{Nd}_{2-x}\text{Ce}_x\text{CuO}_4$ and $\text{Sr}_2\text{CuO}_2\text{Cl}_2$. The combination of the photon circular polarization with the photoelectron spin detection[†] gives access to the character of the photoemission final states, which correspond to the two-hole configurations localized at a (CuO_4) site. In particular the lowest energy state is found to have a very high singlet character in all the measured compounds. This can be considered as a strong indication of the existence and stability of the so-called Zhang-Rice singlets in the layered cuprates. In the case of the Bi2212 superconducting compound[‡] we have verified that the character of the first ionization state does not appreciably change across the critical temperature.

^{*}also: ESRF, BP 220, 38043 Grenoble, France.

[†]L.H. Tjeng *et al*, Phys. Rev. Lett. **78**, 1126 (1997)

[‡]ESRF Highlights 1999, page 47